# Solid Rocket Motor Thrust Oscillations Due To Vortex Shedding Across Inhibitors

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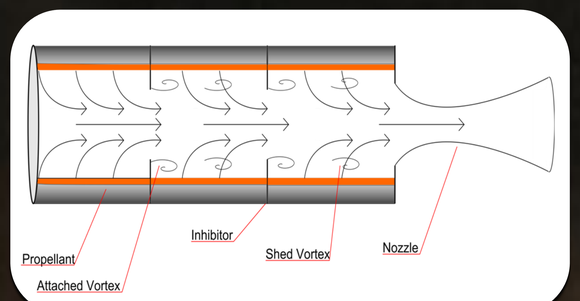
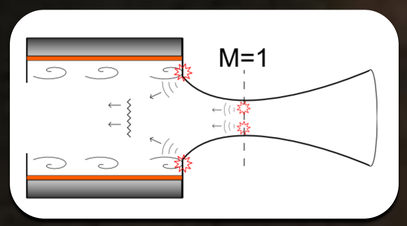
## Introduction:

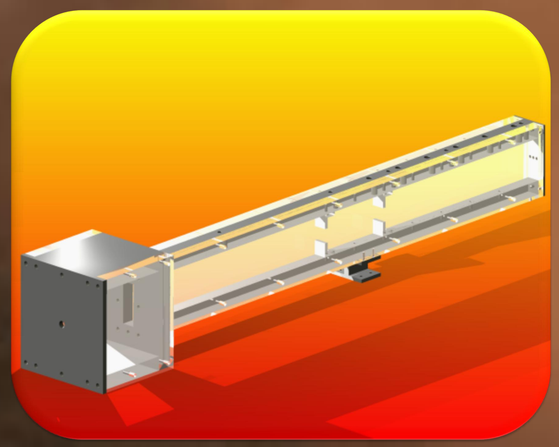
- Vortex shedding across inhibitors in segmented Solid Rocket Motors (SRMs) is believed to be one of the major causes of thrust oscillations during flight.
- These oscillations can be dangerous because their frequencies are nearing the resonant frequency of the motor's structure, certain payloads, and the internal organs of the human body.
- If resonant modes are excited, it is believed that an amplification of the oscillations can occur, leading to damages and potentially **lethal consequences**.
- We are designing a cold-flow test chamber and test bed to correlate inhibitor configurations with vortex shedding frequencies, acoustic modes, and pressure oscillation amplitudes in an environment similar to that of typical full scale SRMs.



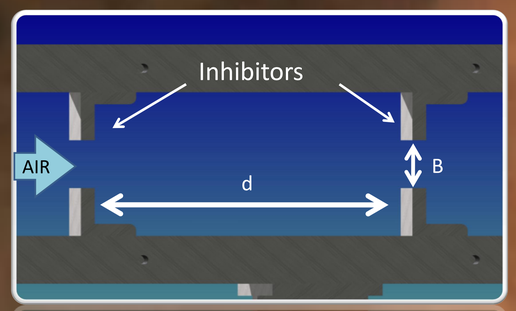
Flow characteristics inside an SRM



Acoustic characteristics inside an SRM


CAD modeling of test chamber


Space Shuttle SRB cutaway view

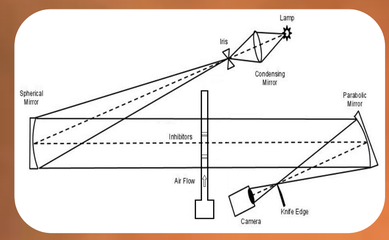


Side view of test section

## Experimental Set Up:

An experimental test bed and the procedures for set up and testing were developed to acquire pressure and acoustic data as well as Schlieren images of the flow characteristics.

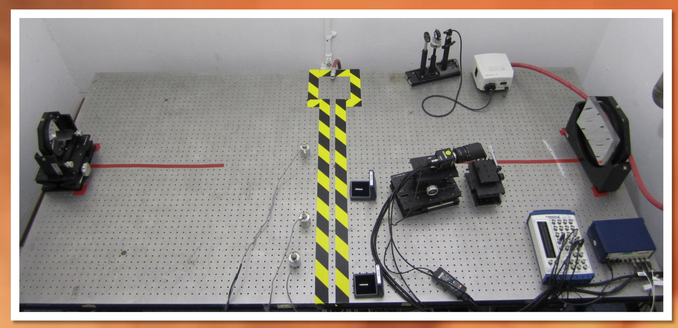
- Z-Type Schlieren Set Up with High Speed Camera
- 3 Static Pressure Transducers
- 2 Dynamic Pressure Transducers (Microphones)
- LabVIEW Control and Data Acquisition Program



Schlieren Imaging Setup


Acquired Schlieren Image, 125psig air jet

## Experimental Test Bed:



## Design of Chamber and Test Section:

- A subscale quasi-1D cold flow test chamber similar to the Space Shuttle SRBs.
- Lateral inhibitor test articles and a test matrix to test various inhibitor geometries, spacing, and longitudinal locations (d/B ratios) in the test chamber.

### Chamber Design

| Design Requirements | Solutions |
|---|---|
| Acoustically isolate test section | • 5:1 Settling chamber-to-test section area ratio |
| Achieve fully developed flow | • Sufficient length between settling chamber and test section |
| Similar fluid environment to SRBs | • Match Mach and Reynolds Numbers |
| Initially Laminar flow | • Settling chamber and honeycomb |

### Test Section Design

| Design Requirements | Solutions |
|---|---|
| Variable Inhibitor Configurations | • Multiple inhibitor bolt-down locations |
| Pressure frequency and amplitude measurements | • 3 pressure transducers with varied locations |
| Acoustic frequency measurements | • 2 Microphones at test section and acoustic boundary condition |
| Variable Exit Conditions | • Three-hole variable nozzle design |

### Desired and Theoretical Chamber Conditions

| | Desired for chamber | Theoretical with chamber |
|---|---|---|
| **Reynolds number** | $> 3x10^3$ | $10^4$ - $10^5$ |
| **Mach #** | 0.02 - 0.2 | 0 - 0.24 |
| **d/B ratios** | 2.909 - 5.33 | 3, 6 |
| **Acoustic Boundary Conditions** | **Closed-Closed** | **Closed-Open** |
| **1L mode (Hz)** | 161.18 | 80.59 |
| **2L mode (Hz)** | 322.35 | 241.76 |

## Future Work:

- Fabrication of test chamber and test articles
- Validation of theoretical design values
- Conducting test matrix, collecting data and images
- Analyze and correlate acoustic and pressure data with images

## Technological Benefits:

- Better understanding of SRM resonance and flow induced vibrations
- Improved designs of inhibitors, casings, and grains such that certain frequencies of induced oscillations can be avoided
- Serves as a model for CFD validation
- Safer and more reliable Solid Rocket Motors

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